Chapter 1

General Introduction and Outline of the Thesis

INTRODUCTION

Butterflyfishes (Chaetodontidae) are small, deep-bodied and colourful fishes. They are mostly diurnal feeders on coral polyps and on other invertebrates (Findley & Findley 2001). Chaetodontids are easily recognizable, site attached, and inhabitants of shallow tropical oceans. Their feeding and social behaviour can be investigated by following marked individuals. As a result, chaetodontids are among the most studied families of coral reef fishes. Distribution patterns, feeding habits, resource partitioning and social behaviour are the main aspects studied.

Despite extensive studies on the ecology of butterflyfishes, little is known about their population dynamics. Data on the behaviour and timing of spawning are available for a few species only (Ralston 1981, Lobel 1989a, 1989b, Tricas & Hiramoto 1989, Yabuta 1997, Yabuta & Kawashima 1997); information on growth is limited to juveniles of a few species (Fowler 1989); and reports on recruitment are scarce (Walsh 1987).

Part A of this chapter provides a summary of the current state of knowledge of the ecology and population dynamics of butterflyfishes. Global distribution, the effect of coral cover on local abundance, feeding habits, territorial behaviour and social systems are discussed. The life history characteristics of butterflyfishes are summarized. Part B summarizes the physical and biological features of the Red Sea. Part C presents the objectives of the study and an outline of the thesis.

A. Butterflyfish Biology

1. Distribution and abundance

Globally 116 chaetodontid species are recognized. The highest diversity of butterflyfishes is recorded from the Indo-Pacific but the diversity decreases as one moves away from this region. Global patterns of distribution may be determined by the evolutionary history of tropical reefs but local distributions may depend on the coral cover. Areas with high coral cover are inhabited by more butterflyfishes than regions with lower cover (Bell & Galzin 1984, Bouchon-Navaro et al 1986). However, the abundance of some chaetodontid species is probably related to the distribution of specific coral genera and not connected with total coral cover. For example, in the East Indo-Pacific the abundance of *Chaetodon trifascialis* was related with the cover of Acropora coral. This fish feeds specifically on *Acropora* and it is hypothesized that the fish and the coral species co-evolved for many years (Reese 1977). Based on this observation Reese (1977) proposed butterflyfishes as

indicators of reef health. However, some workers questioned this hypothesis (Roberts et al 1988).

II. Feeding, territorial and social habits

Chaetodontids live close to the substrate and feed diurnally. Roberts and Ormond (1992) identified five feeding categories among butterflyfishes. These categories are: Obligate hard coral feeders; Feeders on sessile and sedentary invertebrates (including some amount of coral polyp); Feeders on motile benthic invertebrates; Generalist omnivores (opportunistic feeders on broad range of food including algae); and Planktivores (feeding primarily on zooplankton). The majority of the butterflyfishes belong to the first two dietary categories (Reese 1977, Anderson et al 1981, Harmelin-Vivien & Bouchon-Navaro 1982, Harmelin-Vivien & Bouchon-Navaro 1983). Only few species are known to feed on motile benthic invertebrates or on zooplankton (Hobson 1978, Harmelin-Vivien & Bouchon-Navaro 1982).

The feeding habits of butterflyfishes vary among geographical regions. In the Great Barrier Reef about 80% of the butterflyfish species are corallivores. In the western Indian Ocean, the proportion is 72% while in Hawaii it is less than 60%. In contrast, the highest percentage of zooplankton feeders was reported from Hawaii (Sano 1989). Hourigan (1989) attributed the unusually large proportion of planktivores in Hawaii to the absence of many other planktivores from the area.

Butterflyfishes occur as solitary individuals, as pairs, or in small groups (Reese 1977, Burgess 1978, Allen et al 1998). Food resources appear to be the major determinants of different social and mating systems among butterflyfishes. Corallivorous fishes are predominantly pair forming fishes while planktivores usually live in schools (Hourigan 1989). Plankton occurs in patches of varying density around which schools of plaktivorous fish aggregate. Corals, on the other hand, are fixed and predictable in their distribution and can be exhausted if preyed upon intensively.

III. Life history characteristics

Butterflyfishes are broadcast spawners releasing eggs into the water column. The pelagic eggs are externally fertilized and are dispersed by currents. Females typically spawn thousands to hundreds of thousands of eggs at a time. Spawning may take place as often as every two days or once or twice per month. However, usually spawning is seasonal and the spawning season extends for about four months (Thresher 1984).

Embryos hatch about 30 hrs after spawning (Suzuki et al 1980) and the larvae spend an average of 40 days in the plankton before metamorphosing and settling on reefs (Hourigan and Reese 1987). A life history characterized by pelagic eggs and larvae implies absence of parental care for young and eggs. The advantage of this type of life history is the wide dispersal of the eggs and larvae. However, pelagic spawning results in high larval and egg mortality. The loss of eggs and larvae of pelagic spawners is usually compensated by high female fecundity.

Juvenile chaetodontids grow very fast but attain maturity at relatively large size. Compared with pelagic fishes most coral reef species have longer life spans. Many species have extended spawning seasons where large clutches are spawned at intervals over extended breeding periods. The eggs hatch after about 30 hours and develop into pelagic larvae. The larvae spend about 40 days in the water column and end the planktonic life stage by settling on a coral reef as recruits.

Butterflyfishes reach 70-75% of their maximum size and attain maturity at the age of one-year (Ralston 1976, Tricas 1986). Young fish are subject to heavy predation but the predation pressure on adults is relatively low (Reese 1977). The compressed bodies of adult fishes and the presence of sharp spines on the dorsal and anal fins discourage predators from attacking adult butterflyfishes.

There is little information on the longevity of butterflyfishes. The highest longevity recorded was from aquarium fishes where an individual was known to have lived for 25 years (Allen et al 1998). The longevity recorded from natural habitat is much lower. For example, marked pairs of *C. paucifasciatus* lived for at least six years in the Northern Red Sea (Fricke 1986). Reese (1981) observed pairs that lived together for ten years. Compared with longevity estimates for other coral reef fishes, butterflyfish life is much shorter. For example, surgeonfish and parrotfish are known to live for 35 and 50 years respectively (Choat et al 1996).

B. Physical and biological features of the Red Sea

The Red Sea is a long, narrow body of water situated between Northeast Africa and the Arabian Peninsula. The sea extends for about 2000 km in Northeast – Southwest direction and is connected to the Indian Ocean by a narrow and shallow sill at Bab-el-Mendab. The Suez Canal, which was built in 1869, connects the Red Sea with the Mediterranean Sea in the North. The Bab-el-Mendab and the Suez Canal allow only limited exchange of surface water between the Red Sea and the neighbouring water bodies.

Geologically the Red Sea lies between the African and Arabian plates and is essentially a product of their divergence. Crustal sagging is believed to have started

about 180 million years ago but the sea was established as a linear trough about 38 million years ago. The Red Sea is the place where the earth's largest geological feature, the mid-ocean rift system, strikes the continental platform, and splits it. The Red Sea rift has been separating Arabia from Africa for about 70 million years. Widening of the fault paused in the first half of the Tertiary and recommenced between 2 to 5 million years ago (Edwards & Head 1987).

The climate of the Red Sea is largely controlled by the distribution of atmospheric pressure and its changes over a vast area. The pressure centres involved are generally distant from the Red Sea and vary during the course of the year (Edwards 1987). The pressure distributions undergo widespread and sometimes drastic seasonal changes over extensive areas. However, the effects in the Red Sea are small. The weather characteristics over the whole Red Sea basin show a remarkable uniformity throughout the year, with some variation due to the quite large range of latitude. As pointed out by Edwards (1987) this could be attributed to two main factors. Firstly, almost all the air that enters the Red Sea is dry although it may come from different directions. The Red Sea lies within the belt of the Northeast Trade Winds, which forms the basis of much of the airflow to the sea. Further, the surrounding desert and semi-desert areas contribute to the dryness. Secondly, mountain ranges along the side of the Red Sea ensure that the main wind systems blow predominantly along the length of the sea, with only localized air movement at right angles to the shoreline. As a result, the prevailing wind directions are remarkably constant and there is virtually no exchange of air masses with different properties, which might give rise to changeable conditions or spatial variability in the weather.

In the south, measurements near Massawa show the lowest sea surface temperature in February, with values of 25°C. After February, the surface temperature increases gradually to reach a maximum value of 32°C in September. From October to January, temperature declines by about 1°C per month. In the central Red Sea, at about 18°N, a sea surface temperature of 20°C was recorded in February while temperature values above 30°C occurred during the summer months.

There is strong evidence that the production potential of the Red Sea is low. Over most of the basin, thermoclines and haloclines prevent the cycling of nutrients from deeper water to the euphotic zone. There is little nutrient input to the pelagic system from land surface runoff to compensate for the steady loss by sinking of nutrients out of the productive zone. On this basis, productivity can be expected to be low over most of the central Red Sea. Production increases somewhat to the north and south where mixing processes are known to occur. Among these, the inter-oceanic water exchange via the straits of Bab-el-Mendab is the main process. This

exchange is most intense in winter when the plankton-rich Gulf of Aden water flows into the Red Sea at the surface, counterbalanced by an outflow of Red Sea deep water over the Hanish sill.

Seasonal changes of the primary production of the Red Sea are not well studied. The limited studies conducted in the area suggest a relatively higher production in the summer months (Ponomareva 1968). In the southern Red Sea a secondary peak in primary production and phytoplankton standing stock was observed in winter. The effect of summer eutrophication on the plankton biota may, however, be confined to the coastal and the northern and southern ends of the Red Sea. The vast oceanic region between 27°N and 18°N is less affected by seasonal changes. Indeed the most substantial import of phosphate into the Red Sea occurs by subsurface inflow of Gulf of Aden water from July to September. The mass development of blue-green algae provides further evidence of depletion of plant nutrients in oceanic waters during the summer season.

The distribution of corals in the Red Sea is not well known. Some information is available for the Gulf of Aqaba and for some regions along the northern and central coasts of the Red Sea (Bouchon-Navaro 1980, Loya 1972, Roberts et al 1992). The available data suggest that the most common reef type in the area is fringing reef. The reefs in the north and central coasts are up to 40 meters deep and seven depth zones can be distinguished (Roberts et al 1992). In contrast, in the southern Red Sea, the depth of the reef is limited to about 10 m and the reefs are probably less developed. Only four depth zones can be recognized (Roberts et al 1992).

Information regarding the fish communities of the Red Sea is also limited. About 1200 species of fishes are known to occur in the Red Sea (Goren 1984, Ormond & Edwards 1987). The majority of these inhabit coral reefs where they constitute a dominant component of the fish fauna. There are marked differences among the different regions of the Red Sea in fish species richness, assemblage compositions and species' abundance (Sheppard et al 1992).

C. Objectives of the study and outline of the thesis

I. Objectives of the study

The Chaetodontidae are represented by 14 species in the Red Sea and the Gulf of Aden of which seven are endemic (Randall 1983). The Gulf of Aqaba is the most studied part of the Red Sea as far as the ecology of butterflyfishes is concerned. A team of French scientists investigated the feeding (Harmelin-Vivien & Bouchon-Navaro 1982), distribution patterns (Bouchon-Navaro 1980), and resource

partitioning (Bouchon-Navaro 1989). Fricke (1986) studied the social habits and territorial behaviour. Gharaibeh and Hulings (1990) investigated reproductive seasonality of three species.

The butterflyfishes of the northern Red Sea, especially those off the Egyptian and Saudi coasts, have been the subjects of studies by British scientists. The distribution patterns (Roberts & Ormond 1987, Roberts et al 1988, Roberts et al 1992, Righton et al 1996), feeding habits (Ormond 1972) and territorial behaviour (Roberts & Ormond 1992, Wrathall et al 1992, Righton et al 1998) were investigated.

Roberts et al (1992) surveyed 367 sites and investigated the large-scale variation in assemblage structure of chaetodontids and pomacanthids. The study sites were spread throughout most of the Red Sea. Between 6 and 47 sites were visited at every degree latitude from 29°N down to 16°N. Moreover, 20 sites were surveyed in the Gulf of Aden at 12°N. The southern Red, between 16°N and 12°N, was not surveyed during this investigation. The Sudanese, Eritrean and Yemeni coasts of the Red Sea were not included in the study. To date there is no information on the ecology of butterflyfishes from these areas. Roberts et al (1992) suggest the occurrence of marked differences in the assemblage patterns of chaetodontids between the southern Red Sea and the northern and central parts.

Most of the information comes from surveys in the Northern Red Sea and the Gulf of Aqaba. Investigations on feeding, territoriality and social habits were conducted on *C. austriacus* and *C. paucifasciatus*, the dominant chaetodontids in the northern Red Sea. Both species are not reported from the south. On the other hand, nothing is known about the behaviour of *C. larvatus*, the most dominant chaetodontid in the southern Red Sea.

The objective of this thesis is to assess the ecology and population dynamics of chaetodontids in the southern Red Sea. Due to logistic reasons, the fieldwork was carried out mainly on the reefs that are found near Massawa on the Eritrean coast. Distribution patterns were investigated on the reefs around Massawa and in the Dahlak archipelago. Results form this study showed that *Chaetodon larvatus* is the dominant species in the area. Hence, the species was selected for detailed ecological and life history studies. Distribution patterns, feeding habit, territorial behaviour, social systems and population dynamics of *C. larvatus* are investigated.

II. Outline of the thesis

Chapter 2 presents results of surveys of chaetodontid distribution from three regions along the Eritrean Red Sea coast. The data collected are compared with the

regional distribution of butterflyfishes in the Red Sea obtained from the literature. The combined information is assessed and the biogeography of butterflyfishes in the Red Sea and the Gulf of Aden is discussed.

In Chapter 3, the local distribution of chaetodontids is assessed for the central Eritrean coast. Abundance and coral cover data are presented for seventeen sites located near Massawa and in the Dahlak Archipelago. The correlation between fish abundance and coral cover is analysed and the possibility to use the abundance of butterflyfishes as indicators of reef health is discussed.

Feeding habits, social systems and spacing of four common chaetodontid species are compared in Chapter 4. These species are *C. larvatus*, *C. semilarvatus*, *C. mesoleucos* and *Heniochus intermedius*. Diets are analysed by comparing stomach contents. Feeding rates, territorial behaviour, and social grouping of the four species are investigated and compared.

Detailed investigation of social and feeding behaviour of *C. larvatus* is presented in chapter 5. Relationships between feeding rates, territory size and live coral cover are assessed. Food preference is determined by comparing the proportion of corals with the selection consumed by the fish. A comparison is made between the behaviour of *C. larvatus* and that of *C. austriacus*, a territorial corallivore in the northern Red Sea (Wrathall 1992, Righton et al 1996).

In chapter 6 three approaches are used to determine the spawning seasonality of *C. larvatus*. In the first approach, changes in gonad histology is monitored. Egg development provides an indication of the time of spawning. In the second approach, changes in relative gonad mass were monitored by comparing monthly gonadosomatic values over a two years period. In the third approach, field observations were used to determine the spawning period.

Recruitment patterns of *C. larvatus*, *C. semilarvatus* and *Pomacanthus spp*. are the subject of chapter 7. Field data were collected from the reefs around Massawa. Seasonal and inter-annual variations in recruitment are compared by analysing data collected over a four-year period. The field data set is also used to compare spatial aspects of the recruitment patterns.

Growth patterns of *C. larvatus* are investigated in chapter 8. Two independent methods are used. The first method employs readings of growth rings of fish otoliths. Length changes of recruits in the field are monitored as the second method to study the growth of populations of young fish.

Finally, in chapter 9 results from the whole study are summarized and conclusions drawn.